SCIENCE NEWS of the week

Superconductivity: Betwixt and Between

Superconductivity and magnetism are usually incompatible. Superconductivity — the loss of all resistance to electric currents — and ferromagnetism — spontaneous magnetization — appear in certain metals as an effect of cooling. Generally if a metal becomes superconducting, it does not become ferromagnetic, and vice versa. Now, however, a new variety of superconductivity that seems compatible with magnetism has appeared. It is a strangely paradoxical phenomenon, and although theorists expected it, or something like it, to appear, they did not expect it to be as strong as it is.

The new variety is known as heavy electron superconductivity. It appears in materials that are on the border line between those that can become ordinary superconductors and those that become ferromagnets. "These don't know which way to go," says James L. Smith of the Los Alamos National Laboratory in Los Alamos, N.M.

According to Hans R. Ott of the Eidgenössische Technische Hochschule (Federal Polytechnic Institute) in Zurich, Switzerland, this exotic form of superconductivity tends to appear in rare earth actinides, the most studied substances being a uranium-beryllium compound, UBe_{13}, and a uranium-platinum compound, UPt_3. Ott and Smith discussed recent work on them at last week's meeting in Detroit of the American Physical Society.

These materials that are unsure which way to go produce a superconducting state that seems a bit of a hybrid. In normal superconductivity, the superconductor will not permit a magnetic field to penetrate it until the field reaches a certain critical strength (different for each material). At the critical field strength, the superconductor's resistance to the magnetic field fails. The field penetrates, quenches the superconductivity, and the metal returns to its normal state regardless of the temperature. Superconducting magnets use little current and produce no waste heat, but their maximum field strength is limited by this condition. The exotic superconducting state coexists quite well with quite high magnetic fields. If it can be found at temperatures of a few kelvin (rather than fractions of a kelvin), it could produce, in Ott's words, "tremendous magnets."

The exotic state seems to be produced by "heavy" electrons rather than the ordinary conduction electrons. In ordinary superconductivity the conduction electrons, which tend not to be bound to specific atoms, bind together in pairs with their spins directed oppositely. In this state they can move without resistance. The exotic superconductivity seems to involve electrons much heavier than the conduction electrons. Electrons in a metal generally experience a certain drag from their surroundings and so act as if they were heavier than free electrons. The electrons in question act 100 to 1,000 times as heavy as free ones. It seems that they belong to the inner shells of the atoms rather than the outer fringes. How such strongly localized electrons could provide a long-range correlated effect like superconductivity is a paradox the investigators are still working on.

This also seems to be superconductivity with a magnetic moment. The spin of an electrically charged particle makes it a little magnet. If the electrons pair with spins opposite, the pair has no net magnetism. The exotic pairs seem to have net magnetism. They could even have their spins lined parallel. (This parallelism, although it produces a superconducting state, is analogous to what happens when a metal becomes ferromagnetic.) In ordinary superconductivity vibrations of the crystal lattice called phonons bring the pairs together. In the exotic variety some magnetic interaction between the spins seems to do it. If they are parallel, this would be "P wave superconductivity." The ordinary variety is S wave. Ott says, "We do not claim [the work done so far] is a proof of P wave superconductivity." But Smith calls it "a very compelling argument for P wave superconductivity." — *D.E. Thomsen*

APS

Rare earth magnets attract attention

The makers and users of magnets have found their moment, in the form of a new rare earth magnetic compound. Several research groups in the United States and Japan are locked in a race to claim patents and find processing methods that will generate the best and strongest magnets. Many of the key scientists involved in this race met last week at the American Physical Society (APS) meeting in Detroit to discuss the structure of the new compound and theories explaining its unique magnetic properties. Data from measurements of a single crystal of the material were presented that set for the first time a theoretical limit on how good the competing researchers could hope to make their magnets.

The search for the new material began in 1978 when the price of cobalt — the most widely used ingredient in permanent magnets — soared because of political instabilities in the south African countries where it is produced. Last year a few research groups independently came upon the rare earth compound as an alternative to cobalt-based magnets. With some of the technical aspects still to be ironed out, companies — ebullient about the potential for producing inexpensive, lightweight, small magnets — are now planning to market the magnets for uses ranging from stereo speakers, computer disk drives and printers to telecommunications. General Motors, the largest consumer of permanent magnets in the world, plans to use its own brand of the rare earth compound to replace, in 1986, the ferrite magnets or the battery-driven electromagnets currently used in starter motors.

When cooking up magnets, scientists try to invent recipes that maximize two properties: coercivity and energy product. The coercivity is a measurement of how difficult it is to demagnetize a material with an external magnetic field, and is often highest in materials that exhibit some anisotropy, or preferred direction for magnetism. Jan Herbst of General Motors Research Laboratories in Warren, Mich., recently showed, using neutron diffraction of a sample containing the rare earth element neodymium, that the structure of individual crystals of the new material is tetragonal. This contributes to the coercivity because, as Herbst found, the magnetic moments of the neodymium and iron atoms point along the longest axis of the tetragon, defining a preferred magnetic direction.

The coercivity multiplied by the maximum intrinsic magnetic field of the material gives the energy product — a property that is used most often as the yardstick for comparing materials in the magnet race. The higher the energy product, the smaller the magnet required for a given application.

Most of the researchers at the meeting agree with Herbst's analysis that the compound with the highest energy product contains a rare earth (R), iron (Fe) and boron (B) in the phase $R_2Fe_{14}B$. While many rare earths can be used to form this phase, says Herbst, only neodymium and praseodymium have been shown to result in high energy products.

According to Norman Koon of the Naval Research Laboratory in Washington, D.C., who recently measured the maximum manetization of a single crystal of a rare earth compound, the highest possible energy product is 64 million Gauss Oerstead (MGOe — a unit of energy density). However, says Kalatur Narasimhan of Colt Industries, Crucible in Pittsburgh, that's more like a dream, because processing introduces structural defects and impurities that reduce the energy product.

Crucible has achieved the highest en-

Dietrick E. Thomsen and Stefi Weisburd report from the American Physical Society meeting in Detroit.

Mediocosmic quantum effects

Quantum mechanics developed as a theory of behavior in the microcosm—molecules, atoms and smaller things. Sometimes, however, quantum mechanical effects appear in the macrocosm, in things like electronic circuit elements. Josephson junctions are an example. The stepwise (quantized) relations between magnetic fields and electric current characteristics, such as voltage and alternating current frequency, displayed by Josephson junctions makes them useful in many technological applications. They are used particularly to sense and measure weak magnetic fields and to sense or generate electromagnetic radiation. They are also beginning to play a role in computer circuitry.

The Josephson effect requires superconducting materials, metals in which all electrical resistance has been suppressed by chilling. Physicists had not expected that such quantized relationships would appear in normal, resistive conductors. But Yoseph Imry of Tel Aviv University told the meeting that recent experiments show that such quantized relations between magnetic field and electrical current can appear for rings made of normal conductors, provided they are small enough.

These effects depend on interference between different electron waves. One of the important and paradoxical features of the quantum mechanical world is that everything is both a particle and a wave. The effects associated with Josephson junctions arise from interference between different electron waves, whether they reinforce or cancel each other when they come together.

Interference effects are meaningful only in situations where the waves can maintain their phases as they move through space. In a very good vacuum or in a superconductor they can do this. In a normal conductor, the electrons are continually bounced and scattered — this is what electrical resistance amounts to—and the phases of their waves change every time, rendering the situation hopeless as far as interference effects are concerned.

Closer inspection, however, reveals a difference between the two types of scattering that occur. Electrons may be scattered elastically from imperfections and impurities in the crystal lattice or inelastically from vibrations of the lattice. If the bit of conducting material can be made small enough that the inelastic scattering is weak—that is, that the electrons can travel through a large part of it without being scattered that way—interference effects are possible.

At a temperature of one kelvin the characteristic length for a metal can become several thousand atomic lengths, Imry says, so a system of 1,000 to 2,000 atomic lengths should show these effects at "reasonable" temperatures. Semiconductors and semimetals should require less stringent conditions. Microfabrication techniques are advancing so well, he says, that in the not too distant future a wide variety of useful devices should be possible. They would not require the costly and bulky refrigeration techniques (usually with liquid helium) that superconductors need.

Channeling gives protons the bends

Channeling is a technique, indigenous to nuclear and solid state physics, in which a stream of ions is projected down the open pathways lying between the planes of atoms neatly arranged in a crystal. If an ion is aimed correctly into the crystalline landscape, its path will be shaped by the electrostatic forces of the atoms residing in the solid.

One application of this process in high energy physics is to use a bent crystal to deflect particles in an accelerator beam (SN: 1/5/80, p. 5). Richard A. Carrigan and colleagues succeeded in doing just that in January with the M-Bottom beam at the Fermi National Accelerator Laboratory in Batavia, Ill. The researchers replaced a 20 foot, 10 kiloGauss magnet in a secondary beam line with a 1 inch long, 1 millimeter thick silicon crystal that was mechanically bent with a set of screws.

Carrigan reports that the crystal deflected particles, mostly protons, at energies of 400 billion electron volts — twice what had been possible with the magnet. This is the highest energy ever reported for channeling. Other tests, notes Carrigan, indicated that the crystal is very resistant to radiation damage from the impinging particles.

A disadvantage of the crystal is that because of its small size it can only accept about 1 percent of the particles in the beam, and of that, 90 percent is thought to "spin out" like a car going too fast around a curve. Nonetheless, while they can't replace many existing magnets, Carrigan thinks that bent crystals will be useful for a number of specific applications in accelerators.

One future experiment, he says, is to put a series of bent crystals in tandem, leaving spaces between to harvest short lived sub-atomic particles that normally decay before they reach the end of conventional, longer magnets. Another idea, he adds, is to measure a particle's magnetic moment by causing it to precess around the magnetic field, which from the particle's perspective, is created when the crystal zips by. Carrigan also says that other workers have permanently bent a crystal by implanting ions in one side, but these crystals have not yet been used in channeling experiments.

Much noise about electron traps

Noise in electrical systems, like stereo static, is an annoyance to researchers making measurements of very small signals. But noise is also a scientific curiosity, especially "1/f noise," so called because its intensity increases as the frequency (f) drops (SN: 3/22/80; p. 187). 1/f noise weasels its way into virtually every type of material that conducts electricity, as well as some nonelectrical systems such as quasars, music and the weather. Scientists have been searching for the cause of 1/f noise for over half a century.

Theories about 1/f noise in semiconductors have suggested that the responsible parties are defects in a crystal that trap and expel electrons. While 1/f noise has been observed in semiconductor devices in the past, these were too large — and hence contained too many traps — for observers to see the descrete effects of electrons jumping in and out of one trap.

Now Kristin S. Ralls and co-workers at Bell Laboratories in Holmdel, N.J., have fabricated a device small enough to enable the viewing of these individual events. The device is a MOSFET, a Metal-Oxide-Semiconductor Field-Effect Transistor, that has a channel for conducting electricity 1 micron long by 0.1 micron wide. Ralls, who is now a doctoral candidate at Cornell University in Ithaca, N.Y., says that when measuring the electrical resistance of this channel, the researchers obtained a "random telegraph signal," or an irregular series of rectangular pulses varying in width, but not height. This switching, the scientists believe, is due to individual electron traps "turning on and off."

In larger devices, says Ralls, presumably many of these switching sequences overlap to build up a 1/f spectrum. "We don't have the statistics to prove that this is responsible for *all* the low frequency or 1/f noise in larger devices," she says. But the experiment does fit in with theories involving traps and certainly bears further study, she notes.

In addition to its relevance to 1/f noise, the experiment also provided a unique opportunity to study individual traps. The researchers were able to estimate how far each trap was located from the interface between the oxide and the channel and what energies the trapped electrons had. They also discovered that these energies were above that required for conduction. Traps in this regime, say the researchers, have never been studied before.

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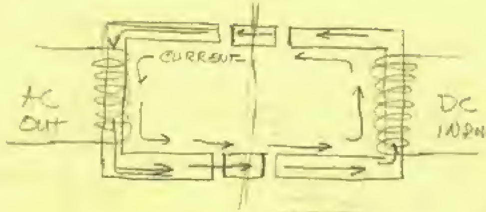

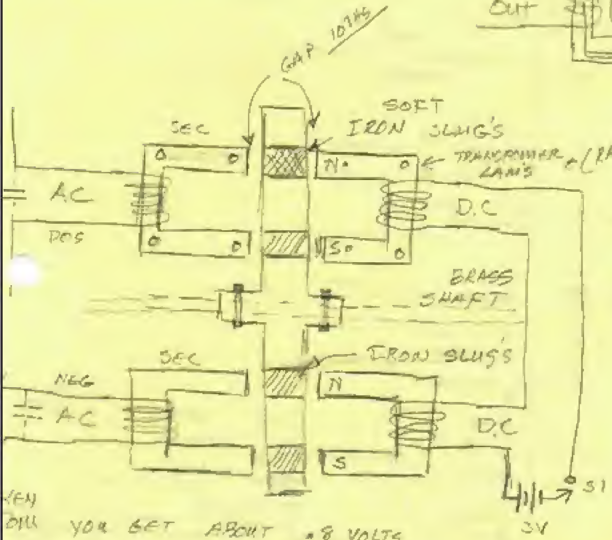

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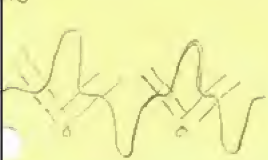

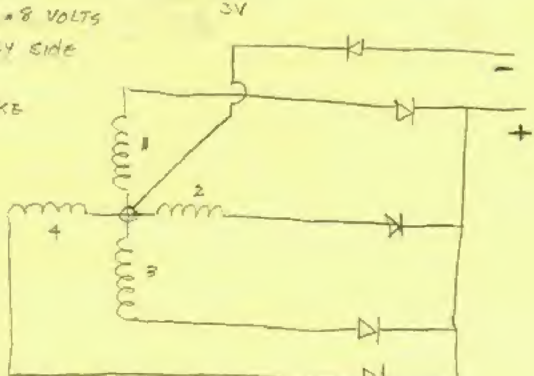

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position giving either a lower or higher voltage, or by commutating or shunting some of the turns of the series field.

Brush Arc Machine. — This was the first arc-light machine to be brought out. It consists of a ring armature having a winding of the open-circuit type. There are a number of spool-wound coils on the armature, diametrically opposite coils being connected in series to an independent pair of commutator segments. The brushes make a series connection of the various groups of coils, the coils of highest e.m.f. being connected in series, those of medium e.m.f. in multiple and those of low e.m.f. being left out of circuit. The numerous field poles are on both sides of the ring armature. The two poles facing each other are of the same polarity so that the flux flows along the ring of the armature from one pole to the next pole on the same side of the ring. Regulation is obtained by shunting field turns and shifting the brushes for good commutation. A rotary oil pump is used as a regulator to move the handle of the field regulator and to move the brushes.

Thomson-Houston Arc Dynamo. — This machine contains a spherical-shaped armature with a three-part open-circuit winding. The three windings being spaced at 120° on a ring armature and connected in "Y," the terminals going to the segments of a three-part commutator. The commutator has air spaces between segments and a jet of air to blow out any arcs between brushes and segments. There are four brushes on the commutator, connected in pairs. At some part of each revolution two coils are in multiple, at other positions only one. A relay moves the brushes so that as the load increases the positive and negative brushes move farther apart thus giving more voltage. As one brush of a pair moves forward the other moves backward thus keeping them symmetrical with respect to the neutral axis. The field structure is of a hollow, cage-like construction.

Wood Arc-light Machine. — This generator has a closed-circuit Gramme ring armature with a commutator having a large number of segments. Regulation is obtained by moving the brushes so as to vary the voltage available and by the use of a high armature reaction balancing the field m.m.f.

HOMO-POLAR GENERATORS. — This type of machine is also sometimes called "acyclic" and was formerly incorrectly called uni-polar. Its method of operation is based on the principle of the Faraday disk, which consisted of a copper disk revolving about an axis and projecting between the poles of a magnet. By this rotation in a magnetic field an e.m.f. is set up between the axis and the periphery of the disk, and if brushes bearing on these two parts are connected to an external circuit a current will flow. The peculiar characteristic of a homo-polar machine is that each conductor always cuts the flux in the same direction, consequently the e.m.f. induced in it is always in the same direction and is not alternating as in the usual direct-current machine. Thus no commutator is required.

This absence of a commutator is the feature which makes the homo-polar machine attractive. The commutator presents many difficulties in high-speed machines to be driven by steam turbines. It is for this application that recent attempts to develop a successful homo-polar machine have been directed. Instead of a commutator, collector rings with brushes are used to collect the current from the moving conductors. These collector rings, however, present difficulties in construction and operation on account of the high peripheral speed at which they must run. The rings are subject to a considerable centrifugal force and there is a tendency of the current to arc between the brush and the collector on account of the high rubbing speed.

Voltage. — The voltage of such a machine is not only unidirectional as in all direct-current machines but is really constant. But since there can be only a

few conductors in series, the voltage generated is very low. The voltage generated per disk or inductor is

$$E = Blv\,10^{-8},$$

where B = magnetic lines per sq. cm., l = length of conductor in cm., v = velocity of conductor in cm. per sec., This is more conveniently expressed,

$$E = \frac{NZ\phi 10^{-8}}{60}\text{ volts,}$$

where N = revolutions per minute, Z = conductors in series, ϕ = total flux traversing gap.

Radial and Axial Types. — There are two types of homo-polar machines, the radial and the axial. The radial type (Fig. 22) is like the Faraday disc and consists of a disc revolving between the two poles of a cylindrical magnet. Brushes bear on the outer rim and the shaft to collect the current. The disc may be made of steel to reduce the reluctance of the magnetic path. The voltage of such a machine is limited to 10 or 15 volts but the current may be

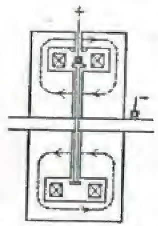


Fig. 22. Radial Type of Homo-polar Generator

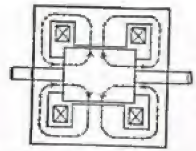


Fig. 23. Axial Type of Homo-polar Generator

very large. A variation of this type has two discs on the same shaft and the magnetic path so arranged that the voltage of the two discs may be added in series by brushes bearing on the peripheries of the two discs. The axial type (Fig. 23) consists of a cylindrical steel armature with copper bars in the surface, the whole revolving in a cylindrical field so arranged that the magnetic flux flows outward from the armature in a radial direction at all points. The several conductors on the armature are connected to slip-rings at both ends, and by means of brushes and stationary conductors, these conductors are connected in series. The voltage of such a machine may be from 40 to 50 volts per conductor.

Data on Large Axial Type Machine. — In the *Trans. A.I.E.E., Vol. 24*, Noeggerath describes a machine of the axial type rated at 300 kw. for 500 volts at 3000 r.p.m. The armature has 12 conductors connected in series for 500 volts. The diameter of the armature is 19 inches and the length 12 inches. The peripheral velocity is 15,000 ft. per min. The armature is of cast steel and has 24 cast steel collector-rings on it. The stationary conductors connecting the collector-rings together are placed in the face of the pole and thus their m.m.f. may be used to balance the armature reaction.

Excitation. — The armature reaction of such machines is very high and has only a distorting effect. However, it weakens the field as the cross magnetiza-

FUNCTIONS OF NUMBERS

No.	Square	Cube	Square root	Cube root	Reciprocal	Circumference	Area
1	1	1	1.0000	1.0000	1.000000000	3.1416	0.7854
2	4	8	1.4142	1.2599	.500000000	6.2832	3.1416
3	9	27	1.7321	1.4422	.333333333	9.4248	7.0686
4	16	64	2.0000	1.5874	.250000000	12.5664	12.5664
5	25	125	2.2361	1.7100	.200000000	15.7080	19.635
6	36	216	2.4495	1.8171	.166666667	18.850	28.274
7	49	343	2.6458	1.9129	.142857143	21.991	38.485
8	64	512	2.8284	2.0000	.125000000	25.133	50.266
9	81	729	3.0000	2.0801	.111111111	28.274	63.617
10	100	1,000	3.1623	2.1544	.100000000	31.416	78.540
11	121	1,331	3.3166	2.2240	.090909091	34.558	95.033
12	144	1,728	3.4641	2.2894	.083333333	37.699	113.10
13	169	2,197	3.6056	2.3513	.076923077	40.841	132.73
14	196	2,744	3.7417	2.4101	.071428571	43.982	153.94
15	225	3,375	3.8730	2.4662	.066666667	47.124	176.71
16	256	4,096	4.0000	2.5198	.062500000	50.265	201.06
17	289	4,913	4.1231	2.5713	.058823529	53.407	226.98
18	324	5,832	4.2426	2.6207	.055555556	56.549	254.47
19	361	6,859	4.3589	2.6684	.052631579	59.690	283.53
20	400	8,000	4.4721	2.7144	.050000000	62.832	314.16
21	441	9,261	4.5826	2.7589	.047619048	65.973	346.36
22	484	10,648	4.6904	2.8020	.045454545	69.115	380.13
23	529	12,167	4.7958	2.8439	.043478261	72.257	415.48
24	576	13,824	4.8990	2.8845	.041666667	75.398	452.39
25	625	15,625	5.0000	2.9240	.040000000	78.540	490.87
26	676	17,576	5.0990	2.9625	.038461538	81.681	530.93
27	729	19,683	5.1962	3.0000	.037037037	84.823	572.56
28	784	21,952	5.2915	3.0366	.035714286	87.965	615.75
29	841	24,389	5.3852	3.0723	.034482759	91.106	660.52
30	900	27,000	5.4772	3.1072	.033333333	94.248	706.86
31	961	29,791	5.5678	3.1414	.032258065	97.389	754.77
32	1,024	32,768	5.6569	3.1748	.031250000	100.53	804.25
33	1,089	35,937	5.7446	3.2075	.030303030	103.67	855.30
34	1,156	39,304	5.8310	3.2396	.029411765	106.81	907.92
35	1,225	42,875	5.9161	3.2717	.028571429	109.96	962.11
36	1,296	46,656	6.0000	3.3019	.027777778	113.10	1,017.88
37	1,369	50,653	6.0828	3.3322	.027027027	116.24	1,075.21
38	1,444	54,872	6.1644	3.3620	.026315789	119.38	1,134.11
39	1,521	59,319	6.2450	3.3912	.025641026	122.52	1,194.59
40	1,600	64,000	6.3246	3.4200	.025000000	125.66	1,256.64
41	1,681	68,921	6.4031	3.4482	.024390244	128.81	1,320.25
42	1,764	74,088	6.4807	3.4760	.023809524	131.95	1,385.44
43	1,849	79,507	6.5574	3.5034	.023255814	135.09	1,452.20
44	1,936	85,184	6.6332	3.5303	.022727273	138.23	1,520.53
45	2,025	91,125	6.7082	3.5569	.022222222	141.37	1,590.43
46	2,116	97,336	6.7823	3.5830	.021739130	144.51	1,661.90
47	2,209	103,823	6.8557	3.6088	.021276600	147.65	1,734.94
48	2,304	110,592	6.9282	3.6342	.020833333	150.80	1,809.56
49	2,401	117,649	7.0000	3.6593	.020408163	153.94	1,885.74
50	2,500	125,000	7.0711	3.6840	.020000000	157.08	1,963.50

FUNCTIONS OF NUMBERS

No.	Square	Cube	Square root	Cube root	Reciprocal	Circumference	Area
51	2,601	132,651	7.1414	3.7084	.019607843	160.22	2,042.82
52	2,704	140,608	7.2111	3.7325	.019230769	163.36	2,123.72
53	2,809	148,877	7.2801	3.7563	.018867925	166.50	2,206.18
54	2,916	157,464	7.3485	3.7798	.018518519	169.65	2,290.22
55	3,025	166,375	7.4162	3.8030	.018181818	172.79	2,375.83
56	3,136	175,616	7.4833	3.8259	.017857143	175.93	2,463.01
57	3,249	185,193	7.5498	3.8485	.017543860	179.07	2,551.76
58	3,364	195,112	7.6158	3.8709	.017241379	182.21	2,642.08
59	3,481	205,379	7.6811	3.8930	.016949153	185.35	2,733.97
60	3,600	216,000	7.7460	3.9149	.016666667	188.50	2,827.43
61	3,721	226,981	7.8102	3.9365	.016393443	191.64	2,922.47
62	3,844	238,328	7.8740	3.9579	.016129032	194.78	3,019.07
63	3,969	250,047	7.9373	3.9791	.015873016	197.92	3,117.25
64	4,096	262,144	8.0000	4.0000	.015625000	201.06	3,216.99
65	4,225	274,625	8.0623	4.0207	.015384615	204.20	3,318.31
66	4,356	287,496	8.1240	4.0412	.015151515	207.34	3,421.19
67	4,489	300,763	8.1854	4.0615	.014925373	210.49	3,525.65
68	4,624	314,432	8.2462	4.0817	.014705882	213.63	3,631.68
69	4,761	328,509	8.3066	4.1016	.014492754	216.77	3,739.28
70	4,900	343,000	8.3666	4.1213	.014285714	219.91	3,848.45
71	5,041	357,911	8.4261	4.1408	.014084507	223.05	3,959.19
72	5,184	373,248	8.4853	4.1602	.013888889	226.19	4,071.50
73	5,329	389,017	8.5440	4.1793	.013698630	229.34	4,185.39
74	5,476	405,224	8.6023	4.1983	.013513514	232.48	4,300.84
75	5,625	421,875	8.6603	4.2172	.013333333	235.62	4,417.86
76	5,776	438,976	8.7178	4.2358	.013157895	238.76	4,536.46
77	5,929	456,533	8.7750	4.2543	.012987013	241.90	4,656.63
78	6,084	474,552	8.8318	4.2727	.012820513	245.04	4,778.36
79	6,241	493,039	8.8882	4.2908	.012658228	248.19	4,901.67
80	6,400	512,000	8.9443	4.3089	.012500000	251.33	5,026.55
81	6,561	531,441	9.0000	4.3267	.012345679	254.47	5,153.00
82	6,724	551,368	9.0554	4.3445	.012195122	257.61	5,281.02
83	6,889	571,787	9.1104	4.3621	.012048193	260.75	5,410.61
84	7,056	592,704	9.1652	4.3795	.011904762	263.89	5,541.77
85	7,225	614,125	9.2195	4.3968	.011764706	267.04	5,674.50
86	7,396	636,056	9.2736	4.4140	.011627907	270.18	5,808.80
87	7,569	658,503	9.3274	4.4310	.011494253	273.32	5,944.68
88	7,744	681,472	9.3808	4.4480	.011363636	276.46	6,082.12
89	7,921	704,969	9.4340	4.4647	.011235955	279.60	6,221.14
90	8,100	729,000	9.4868	4.4814	.011111111	282.74	6,361.73
91	8,281	753,571	9.5394	4.4979	.010989011	285.88	6,503.88
92	8,464	778,688	9.5917	4.5144	.010869565	289.03	6,647.61
93	8,649	804,357	9.6437	4.5307	.010752688	292.17	6,792.91
94	8,836	830,584	9.6954	4.5468	.010638298	295.31	6,939.78
95	9,025	857,375	9.7468	4.5629	.010526316	298.45	7,088.22
96	9,216	884,736	9.7980	4.5789	.010416667	301.59	7,238.23
97	9,409	912,673	9.8489	4.5947	.010309278	304.73	7,389.81
98	9,604	941,192	9.8995	4.6104	.010204082	307.88	7,542.96
99	9,801	970,299	9.9499	4.6261	.010101010	311.02	7,697.69
100	10,000	1,000,000	10.0000	4.6416	.010000000	314.16	7,853.98

FUNCTIONS OF NUMBERS

No.	Square	Cube	Square root	Cube root	Reciprocal	Circumference	Area
1	1	1	1.0000	1.0000	1.000000000	3.1416	0.7854
2	4	8	1.4142	1.2599	.500000000	6.2832	3.1416
3	9	27	1.7321	1.4422	.333333333	9.4248	7.0686
4	16	64	2.0000	1.5874	.250000000	12.5664	12.5664
5	25	125	2.2361	1.7100	.200000000	15.7080	19.635
6	36	216	2.4495	1.8171	.166666667	18.850	28.274
7	49	343	2.6458	1.9129	.142857143	21.991	38.485
8	64	512	2.8284	2.0000	.125000000	25.133	50.266
9	81	729	3.0000	2.0801	.111111111	28.274	63.617
10	100	1,000	3.1623	2.1544	.100000000	31.416	78.540
11	121	1,331	3.3166	2.2240	.090909091	34.558	95.033
12	144	1,728	3.4641	2.2894	.083333333	37.699	113.10
13	169	2,197	3.6056	2.3513	.076923077	40.841	132.73
14	196	2,744	3.7417	2.4101	.071428571	43.982	153.94
15	225	3,375	3.8730	2.4662	.066666667	47.124	176.71
16	256	4,096	4.0000	2.5198	.062500000	50.265	201.06
17	289	4,913	4.1231	2.5713	.058823529	53.407	226.98
18	324	5,832	4.2426	2.6207	.055555556	56.549	254.47
19	361	6,859	4.3589	2.6684	.052631579	59.690	283.53
20	400	8,000	4.4721	2.7144	.050000000	62.832	314.16
21	441	9,261	4.5826	2.7589	.047619048	65.973	346.36
22	484	10,648	4.6904	2.8020	.045454545	69.115	380.13
23	529	12,167	4.7958	2.8439	.043478261	72.257	415.48
24	576	13,824	4.8990	2.8845	.041666667	75.398	452.39
25	625	15,625	5.0000	2.9240	.040000000	78.540	490.87
26	676	17,576	5.0990	2.9625	.038461538	81.681	530.93
27	729	19,683	5.1962	3.0000	.037037037	84.823	572.56
28	784	21,952	5.2915	3.0366	.035714286	87.965	615.75
29	841	24,389	5.3852	3.0723	.034482759	91.106	660.52
30	900	27,000	5.4772	3.1072	.033333333	94.248	706.86
31	961	29,791	5.5678	3.1414	.032258065	97.389	754.77
32	1,024	32,768	5.6569	3.1748	.031250000	100.53	804.25
33	1,089	35,937	5.7446	3.2075	.030303030	103.67	855.30
34	1,156	39,304	5.8310	3.2396	.029411765	106.81	907.92
35	1,225	42,875	5.9161	3.2717	.028571429	109.96	962.11
36	1,296	46,656	6.0000	3.3019	.027777778	113.10	1,017.88
37	1,369	50,653	6.0828	3.3322	.027027027	116.24	1,075.21
38	1,444	54,872	6.1644	3.3620	.026315789	119.38	1,134.11
39	1,521	59,319	6.2450	3.3912	.025641026	122.52	1,194.59
40	1,600	64,000	6.3246	3.4200	.025000000	125.66	1,256.64
41	1,681	68,921	6.4031	3.4482	.024390244	128.81	1,320.25
42	1,764	74,088	6.4807	3.4760	.023809524	131.95	1,385.44
43	1,849	79,507	6.5574	3.5034	.023255814	135.09	1,452.20
44	1,936	85,184	6.6332	3.5303	.022727273	138.23	1,520.53
45	2,025	91,125	6.7082	3.5569	.022222222	141.37	1,590.43
46	2,116	97,336	6.7823	3.5830	.021739130	144.51	1,661.90
47	2,209	103,823	6.8557	3.6088	.021276600	147.65	1,734.94
48	2,304	110,592	6.9282	3.6342	.020833333	150.80	1,809.56
49	2,401	117,649	7.0000	3.6593	.020408163	153.94	1,885.74
50	2,500	125,000	7.0711	3.6840	.020000000	157.08	1,963.50

FUNCTIONS OF NUMBERS

No.	Square	Cube	Square root	Cube root	Reciprocal	Circumference	Area
51	2,601	132,651	7.1414	3.7084	.019607843	160.22	2,042.82
52	2,704	140,608	7.2111	3.7325	.019230769	163.36	2,123.72
53	2,809	148,877	7.2801	3.7563	.018867925	166.50	2,206.18
54	2,916	157,464	7.3485	3.7798	.018518519	169.65	2,290.22
55	3,025	166,375	7.4162	3.8030	.018181818	172.79	2,375.83
56	3,136	175,616	7.4833	3.8259	.017857143	175.93	2,463.01
57	3,249	185,193	7.5498	3.8485	.017543860	179.07	2,551.76
58	3,364	195,112	7.6158	3.8709	.017241379	182.21	2,642.08
59	3,481	205,379	7.6811	3.8930	.016949153	185.35	2,733.97
60	3,600	216,000	7.7460	3.9149	.016666667	188.50	2,827.43
61	3,721	226,981	7.8102	3.9365	.016393443	191.64	2,922.47
62	3,844	238,328	7.8740	3.9579	.016129032	194.78	3,019.07
63	3,969	250,047	7.9373	3.9791	.015873016	197.92	3,117.25
64	4,096	262,144	8.0000	4.0000	.015625000	201.06	3,216.99
65	4,225	274,625	8.0623	4.0207	.015384615	204.20	3,318.31
66	4,356	287,496	8.1240	4.0412	.015151515	207.34	3,421.19
67	4,489	300,763	8.1854	4.0615	.014925373	210.49	3,525.65
68	4,624	314,432	8.2462	4.0817	.014705882	213.63	3,631.68
69	4,761	328,509	8.3066	4.1016	.014492754	216.77	3,739.28
70	4,900	343,000	8.3666	4.1213	.014285714	219.91	3,848.45
71	5,041	357,911	8.4261	4.1408	.014084507	223.05	3,959.19
72	5,184	373,248	8.4853	4.1602	.013888889	226.19	4,071.50
73	5,329	389,017	8.5440	4.1793	.013698630	229.34	4,185.39
74	5,476	405,224	8.6023	4.1983	.013513514	232.48	4,300.84
75	5,625	421,875	8.6603	4.2172	.013333333	235.62	4,417.86
76	5,776	438,976	8.7178	4.2358	.013157895	238.76	4,536.46
77	5,929	456,533	8.7750	4.2543	.012987013	241.90	4,656.63
78	6,084	474,552	8.8318	4.2727	.012820513	245.04	4,778.36
79	6,241	493,039	8.8882	4.2908	.012658228	248.19	4,901.67
80	6,400	512,000	8.9443	4.3089	.012500000	251.33	5,026.55
81	6,561	531,441	9.0000	4.3267	.012345679	254.47	5,153.00
82	6,724	551,368	9.0554	4.3445	.012195122	257.61	5,281.02
83	6,889	571,787	9.1104	4.3621	.012048193	260.75	5,410.61
84	7,056	592,704	9.1652	4.3795	.011904762	263.89	5,541.77
85	7,225	614,125	9.2195	4.3968	.011764706	267.04	5,674.50
86	7,396	636,056	9.2736	4.4140	.011627907	270.18	5,808.80
87	7,569	658,503	9.3274	4.4310	.011494253	273.32	5,944.68
88	7,744	681,472	9.3808	4.4480	.011363636	276.46	6,082.12
89	7,921	704,969	9.4340	4.4647	.011235955	279.60	6,221.14
90	8,100	729,000	9.4868	4.4814	.011111111	282.74	6,361.73
91	8,281	753,571	9.5394	4.4979	.010989011	285.88	6,503.88
92	8,464	778,688	9.5917	4.5144	.010869565	289.03	6,647.61
93	8,649	804,357	9.6437	4.5307	.010752688	292.17	6,792.91
94	8,836	830,584	9.6954	4.5468	.010638298	295.31	6,939.78
95	9,025	857,375	9.7468	4.5629	.010526316	298.45	7,088.22
96	9,216	884,736	9.7980	4.5789	.010416667	301.59	7,238.23
97	9,409	912,673	9.8489	4.5947	.010309278	304.73	7,389.81
98	9,604	941,192	9.8995	4.6104	.010204082	307.88	7,542.96
99	9,801	970,299	9.9499	4.6261	.010101010	311.02	7,697.69
100	10,000	1,000,000	10.0000	4.6416	.010000000	314.16	7,853.98

FUNCTIONS OF NUMBERS

No.	Square	Cube	Square root	Cube root	Reciprocal	Circumference	Area
1	1	1	1.0000	1.0000	1.000000000	3.1416	0.7854
2	4	8	1.4142	1.2599	.500000000	6.2832	3.1416
3	9	27	1.7321	1.4422	.333333333	9.4248	7.0686
4	16	64	2.0000	1.5874	.250000000	12.5664	12.5664
5	25	125	2.2361	1.7100	.200000000	15.7080	19.635
6	36	216	2.4495	1.8171	.166666667	18.850	28.274
7	49	343	2.6458	1.9129	.142857143	21.991	38.485
8	64	512	2.8284	2.0000	.125000000	25.133	50.266
9	81	729	3.0000	2.0801	.111111111	28.274	63.617
10	100	1,000	3.1623	2.1544	.100000000	31.416	78.540
11	121	1,331	3.3166	2.2240	.090909091	34.558	95.033
12	144	1,728	3.4641	2.2894	.083333333	37.699	113.10
13	169	2,197	3.6056	2.3513	.076923077	40.841	132.73
14	196	2,744	3.7417	2.4101	.071428571	43.982	153.94
15	225	3,375	3.8730	2.4662	.066666667	47.124	176.71
16	256	4,096	4.0000	2.5198	.062500000	50.265	201.06
17	289	4,913	4.1231	2.5713	.058823529	53.407	226.98
18	324	5,832	4.2426	2.6207	.055555556	56.549	254.47
19	361	6,859	4.3589	2.6684	.052631579	59.690	283.53
20	400	8,000	4.4721	2.7144	.050000000	62.832	314.16
21	441	9,261	4.5826	2.7589	.047619048	65.973	346.36
22	484	10,648	4.6904	2.8020	.045454545	69.115	380.13
23	529	12,167	4.7958	2.8439	.043478261	72.257	415.48
24	576	13,824	4.8990	2.8845	.041666667	75.398	452.39
25	625	15,625	5.0000	2.9240	.040000000	78.540	490.87
26	676	17,576	5.0990	2.9625	.038461538	81.681	530.93
27	729	19,683	5.1962	3.0000	.037037037	84.823	572.56
28	784	21,952	5.2915	3.0366	.035714286	87.965	615.75
29	841	24,389	5.3852	3.0723	.034482759	91.106	660.52
30	900	27,000	5.4772	3.1072	.033333333	94.248	706.86
31	961	29,791	5.5678	3.1414	.032258065	97.389	754.77
32	1,024	32,768	5.6569	3.1748	.031250000	100.53	804.25
33	1,089	35,937	5.7446	3.2075	.030303030	103.67	855.30
34	1,156	39,304	5.8310	3.2396	.029411765	106.81	907.92
35	1,225	42,875	5.9161	3.2717	.028571429	109.96	962.11
36	1,296	46,656	6.0000	3.3019	.027777778	113.10	1,017.88
37	1,369	50,653	6.0828	3.3322	.027027027	116.24	1,075.21
38	1,444	54,872	6.1644	3.3620	.026315789	119.38	1,134.11
39	1,521	59,319	6.2450	3.3912	.025641026	122.52	1,194.59
40	1,600	64,000	6.3246	3.4200	.025000000	125.66	1,256.64
41	1,681	68,921	6.4031	3.4482	.024390244	128.81	1,320.25
42	1,764	74,088	6.4807	3.4760	.023809524	131.95	1,385.44
43	1,849	79,507	6.5574	3.5034	.023255814	135.09	1,452.20
44	1,936	85,184	6.6332	3.5303	.022727273	138.23	1,520.53
45	2,025	91,125	6.7082	3.5569	.022222222	141.37	1,590.43
46	2,116	97,336	6.7823	3.5830	.021739130	144.51	1,661.90
47	2,209	103,823	6.8557	3.6088	.021276600	147.65	1,734.94
48	2,304	110,592	6.9282	3.6342	.020833333	150.80	1,809.56
49	2,401	117,649	7.0000	3.6593	.020408163	153.94	1,885.74
50	2,500	125,000	7.0711	3.6840	.020000000	157.08	1,963.50

FUNCTIONS OF NUMBERS

No.	Square	Cube	Square root	Cube root	Reciprocal	Circumference	Area
51	2,601	132,651	7.1414	3.7084	.019607843	160.22	2,042.82
52	2,704	140,608	7.2111	3.7325	.019230769	163.36	2,123.72
53	2,809	148,877	7.2801	3.7563	.018867925	166.50	2,206.18
54	2,916	157,464	7.3485	3.7798	.018518519	169.65	2,290.22
55	3,025	166,375	7.4162	3.8030	.018181818	172.79	2,375.83
56	3,136	175,616	7.4833	3.8259	.017857143	175.93	2,463.01
57	3,249	185,193	7.5498	3.8485	.017543860	179.07	2,551.76
58	3,364	195,112	7.6158	3.8709	.017241379	182.21	2,642.08
59	3,481	205,379	7.6811	3.8930	.016949153	185.35	2,733.97
60	3,600	216,000	7.7460	3.9149	.016666667	188.50	2,827.43
61	3,721	226,981	7.8102	3.9365	.016393443	191.64	2,922.47
62	3,844	238,328	7.8740	3.9579	.016129032	194.78	3,019.07
63	3,969	250,047	7.9373	3.9791	.015873016	197.92	3,117.25
64	4,096	262,144	8.0000	4.0000	.015625000	201.06	3,216.99
65	4,225	274,625	8.0623	4.0207	.015384615	204.20	3,381.31
66	4,356	287,496	8.1240	4.0412	.015151515	207.34	3,421.19
67	4,489	300,763	8.1854	4.0615	.014925373	210.49	3,525.65
68	4,624	314,432	8.2462	4.0817	.014705882	213.63	3,631.68
69	4,761	328,509	8.3066	4.1016	.014492754	216.77	3,739.28
70	4,900	343,000	8.3666	4.1213	.014285714	219.91	3,848.45
71	5,041	357,911	8.4261	4.1408	.014084517	233.05	3,959.19
72	5,184	373,248	8.4853	4.1602	.013888889	226.19	4,071.50
73	5,329	389,017	8.5440	4.1793	.013698630	229.34	4,185.39
74	5,476	405,224	8.6023	4.1983	.013513514	232.48	4,300.84
75	5,625	421,875	8.6603	4.2172	.013333333	235.62	4,417.86
76	5,776	438,976	8.7178	4.2358	.013157895	238.76	4,536.46
77	5,929	456,533	8.7750	4.2543	.012987013	241.90	4,656.63
78	6,084	474,552	8.8318	4.2727	.012820513	245.04	4,778.36
79	6,241	493,039	8.8882	4.2908	.012658228	248.19	4,901.67
80	6,400	512,000	8.9443	4.3089	.012500000	251.33	5,026.55
81	6,561	531,441	9.0000	4.3267	.012345679	254.47	5,153.00
82	6,724	551,368	9.0554	4.3445	.012195122	257.61	5,281.02
83	6,889	571,787	9.1104	4.3621	.012048193	260.75	5,410.61
84	7,056	592,704	9.1652	4.3795	.011904762	263.89	5,541.77
85	7,225	614,125	9.2195	4.3968	.011764706	267.04	5,674.50
86	7,396	636,056	9.2736	4.4140	.011627907	270.18	5,808.80
87	7,569	658,503	9.3274	4.4310	.011494253	273.32	5,944.68
88	7,744	681,472	9.3808	4.4480	.011363636	276.46	6,082.12
89	7,921	704,969	9.4340	4.4647	.011235955	279.60	6,221.14
90	8,100	729,000	9.4868	4.4814	.011111111	282.74	6,361.73
91	8,281	753,571	9.5394	4.4979	.010989011	285.88	6,503.88
92	8,464	778,688	9.5917	4.5144	.010869565	289.03	6,647.61
93	8,649	804,357	9.6437	4.5307	.010752688	292.17	6,792.91
94	8,836	830,584	9.6954	4.5468	.010638298	295.31	6,939.78
95	9,025	857,375	9.7468	4.5629	.010526316	298.45	7,088.22
96	9,216	884,736	9.7980	4.5789	.010416667	301.59	7,283.23
97	9,409	912,673	9.8489	4.5947	.010309278	304.73	7,389.81
98	9,604	941,192	9.8995	4.6104	.010204082	307.88	7,542.96
99	9,801	970,299	9.9499	4.6261	.010101010	311.02	7,697.69
100	10,000	1,000,000	10.0000	4.6416	.010000000	314.16	7,853.98

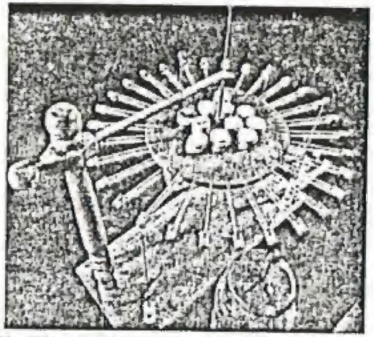
FUNCTIONS OF NUMBERS

No.	Square	Cube	Square root	Cube root	Reciprocal	Circumference	Area
1	1	1	1.0000	1.0000	1.000000000	3.1416	0.7854
2	4	8	1.4142	1.2599	.500000000	6.2832	3.1416
3	9	27	1.7321	1.4422	.333333333	9.4248	7.0686
4	16	64	2.0000	1.5874	.250000000	12.5664	12.5664
5	25	125	2.2361	1.7100	.200000000	15.7080	19.635
6	36	216	2.4495	1.8171	.166666667	18.850	28.274
7	49	343	2.6458	1.9129	.142857143	21.991	38.485
8	64	512	2.8284	2.0000	.125000000	25.133	50.266
9	81	729	3.0000	2.0801	.111111111	28.274	63.617
10	100	1,000	3.1623	2.1544	.100000000	31.416	78.540
11	121	1,331	3.3166	2.2240	.090909091	34.558	95.033
12	144	1,728	3.4641	2.2894	.083333333	37.699	113.10
13	169	2,197	3.6056	2.3513	.076923077	40.841	132.73
14	196	2,744	3.7417	2.4101	.071428571	43.982	153.94
15	225	3,375	3.8730	2.4662	.066666667	47.124	176.71
16	256	4,096	4.0000	2.5198	.062500000	50.265	201.06
17	289	4,913	4.1231	2.5713	.058823529	53.407	226.98
18	324	5,832	4.2426	2.6207	.055555556	56.549	254.47
19	361	6,859	4.3589	2.6684	.052631579	59.690	283.53
20	400	8,000	4.4721	2.7144	.050000000	62.832	314.16
21	441	9,261	4.5826	2.7589	.047619048	65.973	346.36
22	484	10,648	4.6904	2.8020	.045454545	69.115	380.13
23	529	12,167	4.7958	2.8439	.043478261	72.257	415.48
24	576	13,824	4.8990	2.8845	.041666667	75.398	452.39
25	625	15,625	5.0000	2.9240	.040000000	78.540	490.87
26	676	17,576	5.0990	2.9625	.038461538	81.681	530.93
27	729	19,683	5.1962	3.0000	.037037037	84.823	572.56
28	784	21,952	5.2915	3.0366	.035714286	87.965	615.75
29	841	24,389	5.3852	3.0723	.034482759	91.106	660.52
30	900	27,000	5.4772	3.1072	.033333333	94.248	706.86
31	961	29,791	5.5678	3.1414	.032258065	97.389	754.77
32	1,024	32,768	5.6569	3.1748	.031250000	100.53	804.25
33	1,089	35,937	5.7446	3.2075	.030303030	103.67	855.30
34	1,156	39,304	5.8310	3.2396	.029411765	106.81	907.92
35	1,225	42,875	5.9161	3.2717	.028571429	109.96	962.11
36	1,296	46,656	6.0000	3.3019	.027777778	113.10	1,017.88
37	1,369	50,653	6.0828	3.3322	.027027027	116.24	1,075.21
38	1,444	54,872	6.1644	3.3620	.026315789	119.38	1,134.11
39	1,521	59,319	6.2450	3.3912	.025641026	122.52	1,194.59
40	1,600	64,000	6.3246	3.4200	.025000000	125.66	1,256.64
41	1,681	68,921	6.4031	3.4482	.024390244	128.81	1,320.25
42	1,764	74,088	6.4807	3.4760	.023809524	131.95	1,385.44
43	1,849	79,507	6.5574	3.5034	.023255814	135.09	1,452.20
44	1,936	85,184	6.6332	3.5303	.022727273	138.23	1,520.53
45	2,025	91,125	6.7082	3.5569	.022222222	141.37	1,590.43
46	2,116	97,336	6.7823	3.5830	.021739130	144.51	1,661.90
47	2,209	103,823	6.8557	3.6088	.021276600	147.65	1,734.94
48	2,304	110,592	6.9282	3.6342	.020833333	150.80	1,809.56
49	2,401	117,649	7.0000	3.6593	.020408163	153.94	1,885.74
50	2,500	125,000	7.0711	3.6840	.020000000	157.08	1,963.50

FUNCTIONS OF NUMBERS

No.	Square	Cube	Square root	Cube root	Reciprocal	Circumference	Area
51	2,601	132,651	7.1414	3.7084	.019607843	160.22	2,042.82
52	2,704	140,608	7.2111	3.7325	.019230769	163.36	2,123.72
53	2,809	148,877	7.2801	3.7563	.018867925	166.50	2,206.18
54	2,916	157,464	7.3485	3.7798	.018518519	169.65	2,290.22
55	3,025	166,375	7.4162	3.8030	.018181818	172.79	2,375.83
56	3,136	175,616	7.4833	3.8259	.017857143	175.93	2,463.01
57	3,249	185,193	7.5498	3.8485	.017543860	179.07	2,551.76
58	3,364	195,112	7.6158	3.8709	.017241379	182.21	2,642.08
59	3,481	205,379	7.6811	3.8930	.016949153	185.35	2,733.97
60	3,600	216,000	7.7460	3.9149	.016666667	188.50	2,827.43
61	3,721	226,981	7.8102	3.9365	.016393443	191.64	2,922.47
62	3,844	238,328	7.8740	3.9579	.016129032	194.78	3,019.07
63	3,969	250,047	7.9373	3.9791	.015873016	197.92	3,117.25
64	4,096	262,144	8.0000	4.0000	.015625000	201.06	3,216.99
65	4,225	274,625	8.0623	4.0207	.015384615	204.20	3,318.31
66	4,356	287,496	8.1240	4.0412	.015151515	207.34	3,421.19
67	4,489	300,763	8.1854	4.0615	.014925373	210.49	3,525.65
68	4,624	314,432	8.2462	4.0817	.014705882	213.63	3,631.68
69	4,761	328,509	8.3066	4.1016	.014492754	216.77	3,739.28
70	4,900	343,000	8.3666	4.1213	.014285714	219.91	3,848.45
71	5,041	357,911	8.4261	4.1408	.014084517	223.05	3,959.19
72	5,184	373,248	8.4853	4.1602	.013888889	226.19	4,071.50
73	5,329	389,017	8.5440	4.1793	.013698630	229.34	4,185.39
74	5,476	405,224	8.6023	4.1983	.013513514	232.48	4,300.84
75	5,625	421,875	8.6603	4.2172	.013333333	235.62	4,417.86
76	5,776	438,976	8.7178	4.2358	.013157895	238.76	4,536.46
77	5,929	456,533	8.7750	4.2543	.012987013	241.90	4,656.63
78	6,084	474,552	8.8318	4.2727	.012820513	245.04	4,778.36
79	6,241	493,039	8.8882	4.2908	.012658228	248.19	4,901.67
80	6,400	512,000	8.9443	4.3089	.012500000	251.33	5,026.55
81	6,561	531,441	9.0000	4.3267	.012345679	254.47	5,153.00
82	6,724	551,368	9.0554	4.3445	.012195122	257.61	5,281.02
83	6,889	571,787	9.1104	4.3621	.012048193	260.75	5,410.61
84	7,056	592,704	9.1652	4.3795	.011904762	263.89	5,541.77
85	7,225	614,125	9.2195	4.3968	.011764706	267.04	5,674.50
86	7,396	636,056	9.2736	4.4140	.011627907	270.18	5,808.80
87	7,569	658,503	9.3274	4.4310	.011494253	273.32	5,944.68
88	7,744	681,472	9.3808	4.4480	.011363636	276.46	6,082.12
89	7,921	704,969	9.4340	4.4647	.011235955	279.60	6,221.14
90	8,100	729,000	9.4868	4.4814	.011111111	282.74	6,361.73
91	8,281	753,571	9.5394	4.4979	.010989011	285.88	6,503.88
92	8,464	778,688	9.5917	4.5144	.010869565	289.03	6,647.61
93	8,649	804,357	9.6437	4.5307	.010752688	292.17	6,792.91
94	8,836	830,584	9.6954	4.5468	.010638298	295.31	6,939.78
95	9,025	857,375	9.7468	4.5629	.010526316	298.45	7,088.22
96	9,216	884,736	9.7980	4.5789	.010416667	301.59	7,238.23
97	9,409	912,673	9.8489	4.5947	.010309278	304.73	7,389.81
98	9,604	941,192	9.8995	4.6104	.010204082	307.88	7,542.96
99	9,801	970,299	9.9499	4.6261	.010101010	311.02	7,697.69
100	10,000	1,000,000	10.0000	4.6416	.010000000	314.16	7,853.98

Fig. 1. A replica of Franklin's electrostatic motor. Rotation is achieved by corona discharge.



ELECTRIC POWER FROM THE EARTH

THE SEARCH FOR NATURAL SOURCES OF ENERGY GOES ON

BY L. GEORGE LAWRENCE

MOST economists agree that present standards of living can be maintained only if more electrical power is made available every year. Unfortunately, to obtain power from traditional sources means pollution; getting more power from these sources means more pollution. Consequently, it comes as no surprise that a great deal of effort and capital are being invested in attempts to find "cleaner" sources of electricity than we have been using. Along these lines, we find renewed interest not only in geoelectric phenomena, but also in exotic energy-conversion schemes with excellent promise for the not-too-distant future. So far, everything has been very experimental, but, at last, a beginning has been made.

To geophysicists and electrical engineers, our planet is a powerful generator of dc power in the trillion-kilowatt (10^{12}) range. Its dynamo action is due partially to axial rotation and the magnetic interaction in ionospheric fields and partially to thermocouple-type phenomena between the hot magma of the earth's core and the cold crust. The natural earth, or telluric, currents flow in large "sheets." While apparently weak, telluric currents can attain immense magnitudes in submarine telephone cables when certain geoelectric conditions coincide. (Submarine cables between the U.S. and Europe frequently produced terminal voltages up to 2500 volts.)

The question is, how can we harness this power? Studies are currently under way to determine how to increase the current flow in ore-bearing bodies and store the electrical energy potentials in buffers or accumulators for later use. Special provisions must be made for possible telluric polarity changes to safeguard dc-to-ac converter systems.

Another force that is available for immediate use is that of electrostatic energy. Electric fields, currents, and conductivity, as well as positive and negative ions of greatly varying size, constitute the principal electrical properties of the atmosphere in fair weather. In the altitude between 30 and

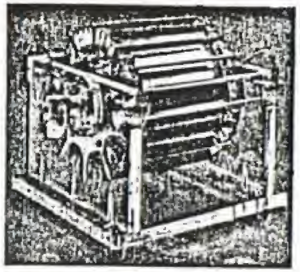


Fig. 2. The electrostatic motor shown here can develop 1/10 horsepower by using an antenna carried by a balloon.

70 kilometers, atmospheric studies of electricity and ionospheric physics merge.

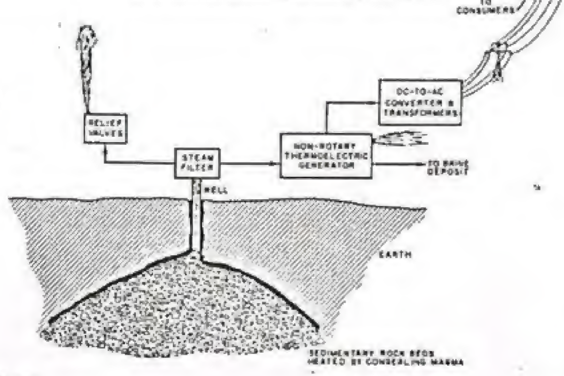
Remarkably enough, Benjamin Franklin was among the very first people to envision the enormous potential of static electricity in industry. An exact replica of his electrostatic corona motor, recreated at West Virginia University by Dr. Oleg Jefimenko and David K. Walker, is shown in Fig. 1. The propulsive force for the motor disk is obtained from discharge electrodes placed at strategic points around the disk's circumference. A Leyden jar (lower right in photo) serves as the high-voltage storage/discharge component.

The latest version of the WVU electrostatic motor is shown in Fig. 2. Like similar machines, the insulated knife-edge electrodes generate a corona that charges or ionizes air particles floating by. The latter transfer their charge to the nearest part of the plastic rotor and charge it. Now, once a spot on the rotor takes a charge, it will be repelled by simple electrostatic force from the charging electrode. A simultaneous attraction toward the other, oppositely-charged, electrode takes place. So, when the charged portion of the rotor reaches the opposite electrode, another corona discharge takes place, reversing the polarity, and the cycle repeats itself.

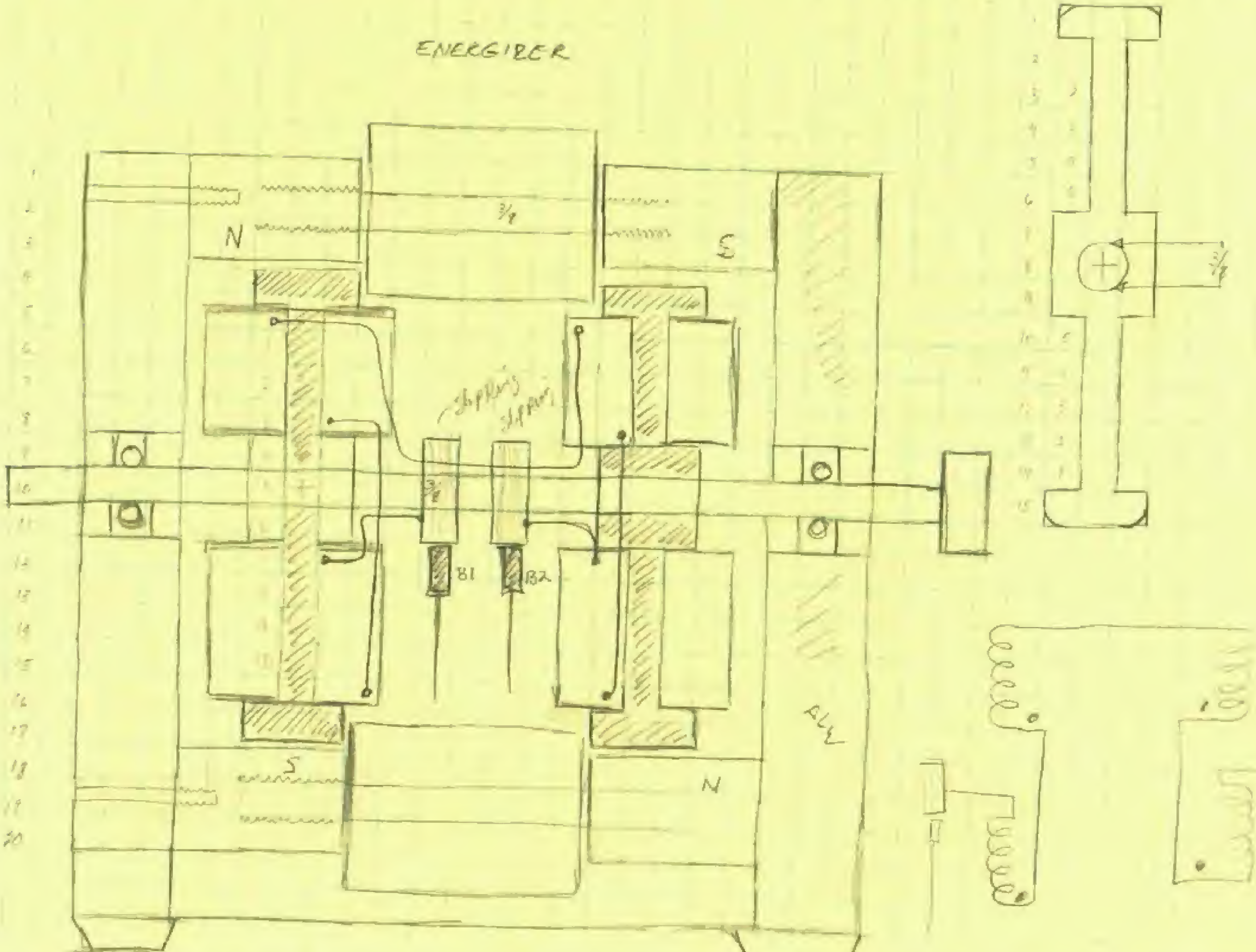
The Jefimenko model shown can develop 0.10 horsepower if energized by a 30,000-volt electrostatic generator. Operation by natural electrostatic electricity requires that the feeder antenna be carried aloft by kite or balloon to a height of 200 to 300 ft above ground to obtain an operating potential of about 20,000 volts. Of course, all of this sounds promising, but our society is in a hurry and needs large amounts of power now.

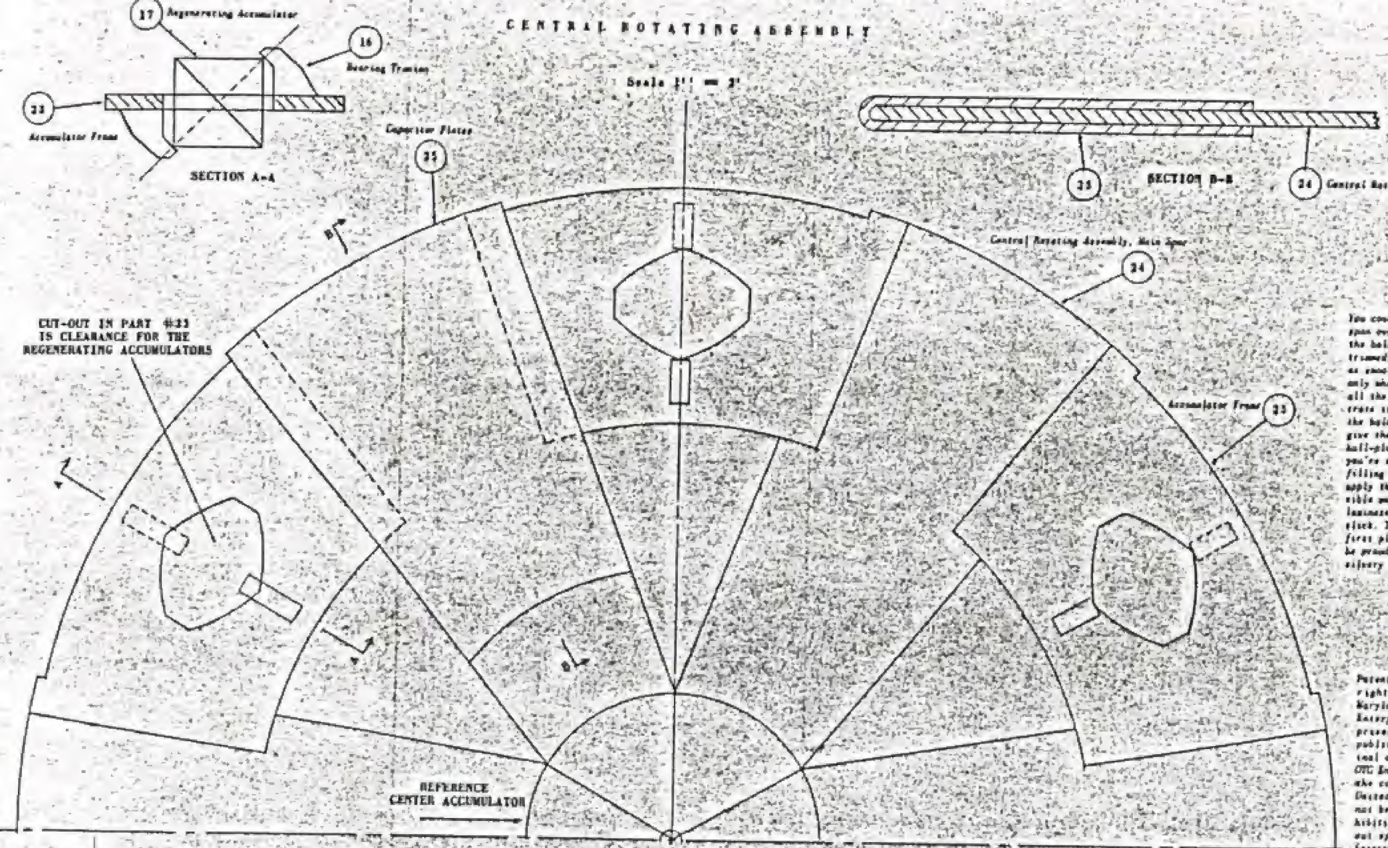
More Practical Approaches. Presently, considerable attention and a great deal of money are being used to exploit hot springs and natural geysers as sources of power.

Fig. 3. Direct-conversion geothermal power system.



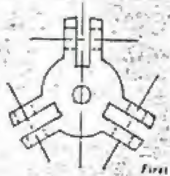
ENERGIZER





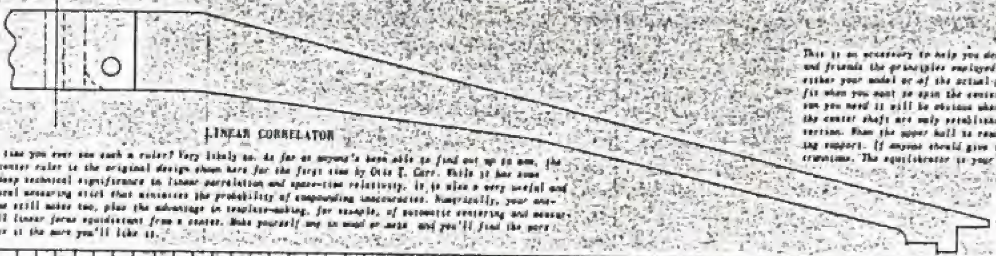
HULL STRUCTURE

You cover the hull structure with the Silkspan over 1/32 balsa. After you fasten the balsa sheets and get them nicely smoothed, trimmed, and filled, stretch the Silkspan as smoothly as you can and fasten it with glue only where you need to hold it fast around all the edges. Your dope coats will then penetrate its pores, laminate it permanently to the balsa, and let it shrink "skin-tight" to give the simulated effect of the actual metal hull-plates. SO REMEMBER : : . when you're sanding those thin-sheets of balsa and filling the joints and pores, that once you apply the Silkspan you've had all the possible way to remove it once it's doped and laminated and you wish it looked a bit more slick. Take your time—do it right in the first place, and you'll have a ship-shape to be proud of, with its broad expanse of silvery hull shining like a star.



CENTRIPETAL EQUILIBRATOR

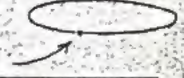
This is an accessory to help you demonstrate the inner workings of your OTC-X1 Spacecraft and teach your family and friends the principles employed in all its component assemblies. It is not itself an inherent part of either your model or of the actual passenger-carrying craft. You snap it into place by light-pressured forcing fit when you want to spin the center disc clockwise in opposition to the hull in counter-rotation. The reason you need it will be obvious when you get your craft built and assembled. The hull's two bearing supports on the center shaft are only established when the upper-hull assembly is interlocked into place with the lower section. When the upper hull is removed the lower will be inclined to wobble because it has only the one bearing support. If anyone should give it a careless spin it would probably break some of the magnets or generator trunnions. The equilibrator is your means of prevention.

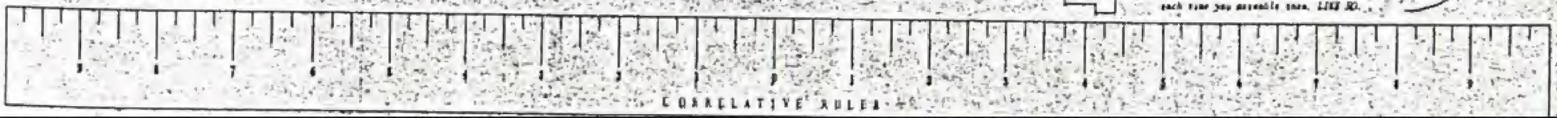


LINEAR CORRELATOR

First time you ever saw such a ruler? Very likely so. As far as anyone's been able to find out up to now, the zero-center ruler is the original design shown here for the first time by Otis T. Carr. While it has some very deep technical significance in linear correlation and space-time relativity, it is also a very useful and practical measuring stick that minimizes the probability of compounding inaccuracies. Numerically, your one-and-one still makes two, plus the advantage in template-making, for example, of automatic centering and measuring all linear forms equidistant from a center. Make yourself one in wood or metal and you'll find the more you use it the more you'll like it.

You'll want to make a tiny mating-mark on the outside of each hull assembly as a convenient reference point for putting the two together where they're intended to go each time you assemble them. LIKE SO. . .





WHO QUALIFIES?

And What Does The Offering Circular Mean When It Says "Even Fly It Yourself (Under Proper Qualification)"?

It won't be too long before OTC-X1 Spacecraft and their offspring will be riding the airlanes and Spacelanes all over this earth and throughout our solar system.

It won't be too long before people like you and the boy next-door will be piloting, flying, and navigating practical electrified flight models on scheduled runs between cities on the several planets we know of, or even the several billion we've yet to discover.

And it won't be long before the OTC energy systems are as familiar and plentiful as Mr. Tesla's AC motors.

Then why are we holding back the several sheets of plans that reveal the exact markings and wirings, the circuitry and controls, and the internal cellular construction of the accumulators and generators that would show you exactly how to energize and fly a Spaceform miniature using real space forces?

Well, start with conventional aircraft. Ask yourself what the conditions would be under which you would build and fly one of your own with no capable supervision, training, or licensing, or even an activated model of one?

The answers are obvious. The average private individual wouldn't dream of attempting such a thing. Nor would we think of carrying even a small power-model loose into the airlanes because we automatically realize what a hazard it would be to craft already in the air under intelligent guidance.

It begins to be obvious then, that it will take training, education, supervision, authorization, and most of all the proper and adequate facilities for qualified construction and handling of OTC-X1 Spacecraft that will operate on their own built-in power systems and levitate their way around the [illegible] force-fields.

All this is more important and more critical when you consider that the force power-packages, which activate our OTC Spacecraft and other energy systems, are able to develop controllable forces of titanic magnitude, and naturally, in untrained hands or in under-equipped laboratories, such forces [illegible] could cause real harm.

OTC wants you to learn, train, and qualify. OTC wants you to prepare to enter and join the Interplanetary Space Age, enjoy its benefits, and share its abundant blessings. And OTC will help you in every way possible.

We are now, and will be continually preparing explanatory technical literature, lesson-plans, study courses, and we will have lecturers touring the world's schools, colleges, and institutions with travelling exhibits to help one and all get into high gear for space-age activities.

But since this is for tomorrow, who in the world qualifies today, and what ones they have and need to start with the program right here and now?

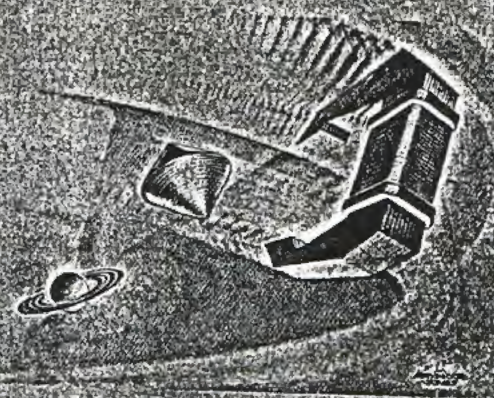
One good example would be people already engaged in aircraft production or the making of energy machines of other kinds.

Others would be mature professional people on all levels and in all categories of laboratory research and development in our institutions and industries.

And you are one?

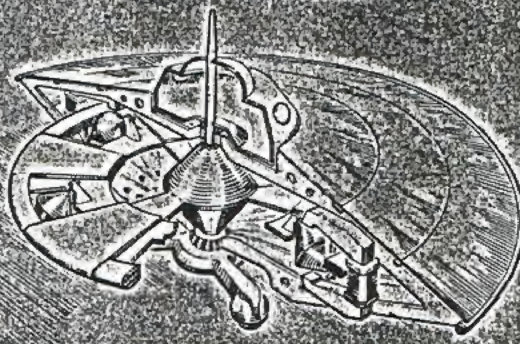
Fill out the enclosed questionnaire; let us know which way you want to go.

We'll help in every way we can.



SPACEFORMS IN MOTION OF PRESSURE

The dimensions of pressure and weight [illegible] the dimension of [illegible] Therefore, motion is dimensionally [illegible].



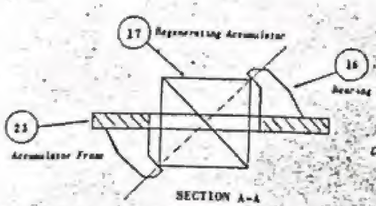
X-RAY VIEW OF CUTAWAY REGIONS

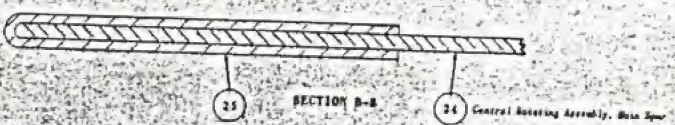
This view through the hull, from the outside [illegible] the fuselage, [illegible] you see every component [illegible] is assembled and established.

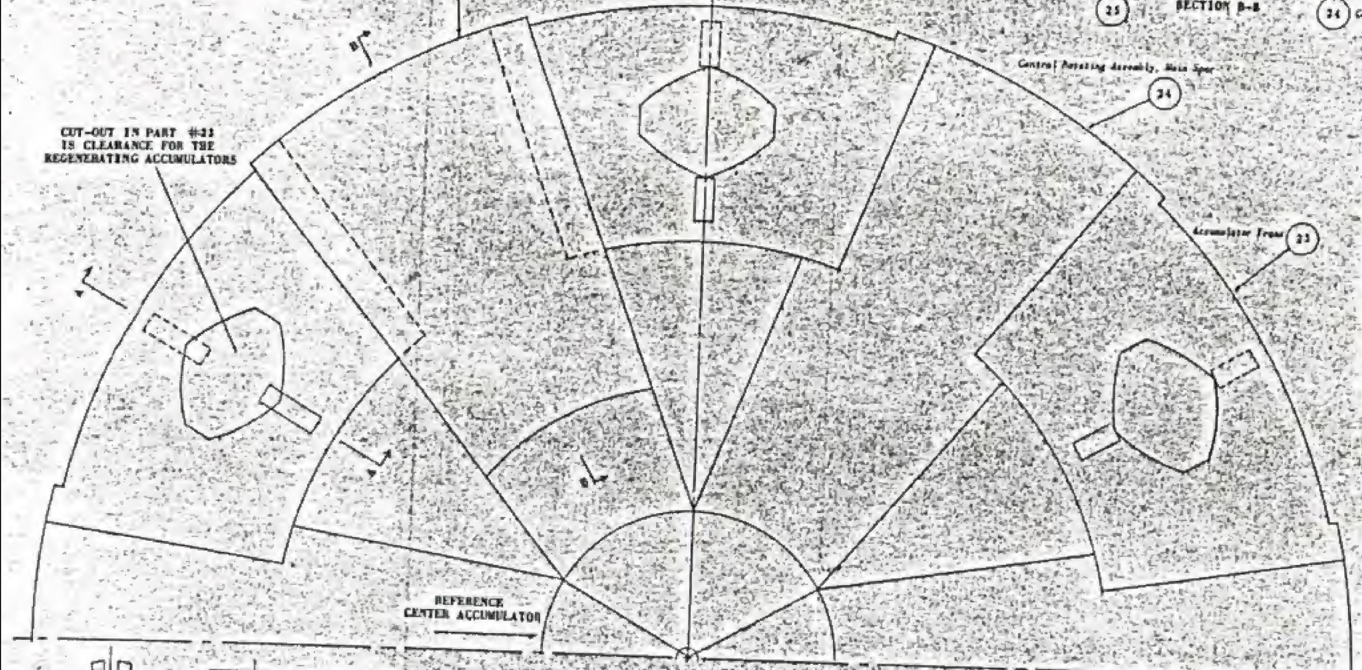
EVOLUTION OF RUMOR INTO FACT

Flight-conception rendering of your model OTC-X1 by artist [illegible] shows astonishing similarity to "saucers" from other planets.

CENTRAL ROTATING ASSEMBLY







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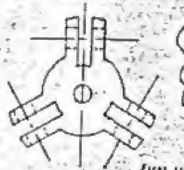

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129 Complete Experiment-Guaranteed, $5.00 plus $.30 SASE, proves energy not conserved. JW Ecklin, 6143K Edsall Rd., Alexandria, VA 22304. July Science #4.

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May 23, 1984

To Scientific American
Science News

President Ronald Reagan
The White House
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W..., DC 20006

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& also in Jan Popular Science & August High Technology

*IS IN ERROR.

Some clips work much better than others.

Dear Mr. President:

Enclosed is an actual experiment (or a fun toy) that proves the law for the conservation of energy ^ Science was always based on experiment until this one came along. Also enclosed is a 4/13/1984 letter printed in The Alexandria Gazette which explains the theory and operation of the toy. Also enclosed (over) is USAA6 which explains how to amplify by many trillions the energy that is captured, stored and reversed in the paper clip to enable it to lift a much heavier ball. The magnet is permanent as all manufacturers claim in their advertisements.

The reason I bother you with this toy is because the above papers have been translated into 7 foreign languages. This is extremely dangerous as subs will no longer need turbines which are extremely noisy. Planes will be able to operate as long as nuclear subs and could stay up much longer if food could be supplied to the crew. If planes were no larger than a 747 we could have dozens aloft anywhere in the world at the same time. I'm sure you can think of many other dangerous (H. Tanks, etc.) scenarios.

I believe the safety of the USA is in grave danger but I can't get the science community (especially in government) or the mass media to inform the public. Knowledge is power but trying to keep this secret can be extremely dangerous as it will only be a secret in this country.

CAUTION: When a scientist sees the ball hanging from the clip they see no motion and say no work is being done so no energy is required. It is WHEN the ball resting on the magnet attracts the clip that energy is captured and stored. Be sure tip of clip is clean.

Sincerely,
John W. Ecklin
John W. Ecklin

Science Digest Dr. J. Bernstein, Omni, Dr. L. Wharton NASA, R-E, T. Valentine, Omni, Analog, Jerry Bogart EMR, IEEE

NOTES #2-Why should a 7,000 times easier path for a magnetic field through the clip and ball compared to air weaken a magnet?? There is something about the tension of the clip and ball together that stores more energy than when they are apart. Be sure tip of the clip is clean.

It is said over 90% of the World's scientists are alive today. You have just done an experiment that proves them all wrong.

See how to love thy neighbor. ♡

407c.

co:file
encl:as

cc/w/encl + Kit to Sam Zagoria + VE Kohn TWP, Stan Parris, W. Fauntroy, GW Bekas, OE-RI, DOE, AIP, AAAS, Johnny Carson, Dan Rather, J.D. Dingell, AE Fitzgerald, DISCOVER, Hon. John Lehman, Dr. R.D. DeLauer, Jack Anderson, GC Galine, Dr. J. Asimov

you can't find a ball use another clip & thread and tie on weight.

cc: Dr. HW Milnes, Dr. RI Cole, Dr. M. Brill, MJ Gibson, Dr. AL Hammond, USN-MOR, Time, Life, Newsweek, WGBH, WETA, WRC, Dr. FJ Dyson, GP Tewett, RB Smith, EPRI, C. Walters Jr., Dr. A. Rich, Dr. J. Walker, FA Rogers, WDVM-TV, J. Greenburg, Dr. GH Beggs, Dr. H Resnick, Dr. PB Van Ready, Dr. CE Swartz, Sen. J. Glenn, WASS, RH Richardson, Dr. OB Montgomery NML at MIT, Dr. SQ Nasar

Have you hugged a child or strengthened a magnet today? -or- Some of 82 x ∞ -or- Real Atomic Energy -or- Capturing a dab of 82 times infinity -- love is showing this to a neighbor. ♡

An ordinary iron atom has 82 major particles, 30 neutrons, 26 protrons and 26 electrons. All these particles have the same angular momentum which according to quantum physics never changes. Thus each of these perpetual motions has infinite energy.

Kids prove this by doing anti-gravity experiments or fun magic tricks that strengthens permanent magnets. When you buy a magnet the manufacturer usually suggests you install a keeper to keep it stronger longer. A paper clip and a 3/8ths inch diameter ball bearing form a partial keeper. In each of these iron atoms there are 4 unpaired electrons in the 3d sub-shell of the M shell. The majority of these unpaired electrons are so easily aligned to spin in the same direction they make a 1/4 inch thick by 1/2 inch in diameter ceramic button magnet with poles on the round flat surfaces stronger longer.

Set magnet on a horizontal steel surface and put the ball at the center of the magnet. Tie thread to clip and dangle clip near the ball. Energy is stored in the clip in that tiny instant when the ball attracts the clip and the clip strikes the ball. To reverse the energy stored in the clip just turn the magnet over.

You can now pull up on the thread and tape it to an overhang. You will have the ball under the clip and it will hang there for months or years. If you ever separate the ball and clip you will have to go back and strengthen the magnet a bit to again hang the ball below the clip. by JW. Ecklin, 6143K Edsall Rd., Alexandria, VA 22304 Note--Much more energy is captured in the clip than joining 2 atoms or splitting an atom in fusion and fission or nuclear energy. Note #2-Most people who see this "elegant experiment" say, oh how cute. A few look a little further and become billionaires, while another 50 or so, who are not that interested in money and power, become millionaires.

Ecklin's paradox or 0 > c. If we consider electric, magnetic & electromagnetic radiation (sunlight) nothing material Einstein was saying information can travel faster than c, the speed of light, or was he? --New Para--Consider 3 mobile CBs with 2 used as stationary detectors (sds) a mile apart alongside a straight road. Have a car close at 55 mph with the CB unmodulated so it is crystal controlled. Both sds receive a higher frequency than the car CB always transmits. When car passes first sd it suddenly gets a lower frequency than the car transmits while the sd almost a mile ahead is still receiving a higher frequency. This proves c is a constant to the source but also gets the velocity of the source. --3rd para-- Repeat this experiment but talk on the car CB to prove information can simultaneously travel faster and slower than c. Einstein is still correct because the modulated wave is nothing material. So nothing travels faster than light or zero is greater than c.

cc: AH Klotz, ...

June 8, 1984

Mr. J. Bedini
13410 Sayre Street
Sylmar, CA 91342

Dear Mr. Bedini,

Thank you very much for the video tape on Newman's motor. I've watched it many times and found it very interesting. I hope Newman wins his case with the patent office but I don't think he will. I think there is too much pressure from some groups of people to not allow this to succeed.

If, by chance, you get a copy of Newman's original paper I would be most grateful to read it. This is not to rob him of his ideas but to learn; my curiosity has got the better of me.

I hope the spooks are not getting your morale down. I understand they can be most frustrating, as long as there are no bodily threats. I have been having problems at work. The institute has not been getting contract funds as they should so they cut a few workers to a four-day work week; I was one of them. Most recently, I haven't had a chance to perform many experiments, but plan to as soon as time permits.

I believe that strong magnetic fields are non-linear, which produce some phenomena. This might explain why some experimenters have unusual claims, i.e. Newman's motor. Not only are strong magnetic fields non-linear but also very high potentials would be non-linear. This also happens with very strong and short coherent light pulses. This type of light could go through opaque objects.

I've mentioned on the phone to you that I am very interested in making some sort of transmitter and receiver based on this type of technology. Could be called "A" field engineering or "scalar field". By the way, an "A" field would always be perpendicular to the "B" field. Just because the "B" fields cancel, the "A" fields may not, (i.e. toroids and other special wound coils). See Drawing enclosed for some guesses as to how this might be done.

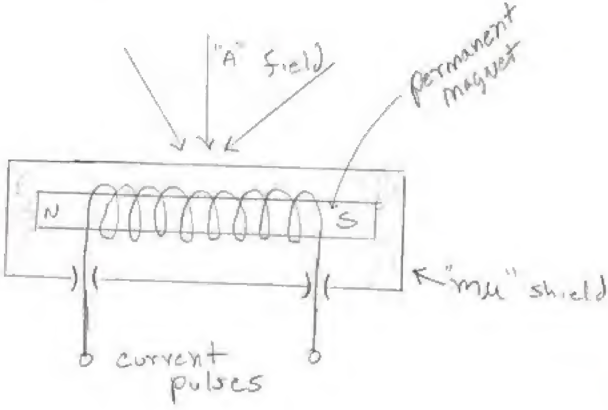
I am very interested in your work and would like to keep in touch to share ideas. Hoping to meet you and Peter Lefferts at the get-together on July 7, 1984.

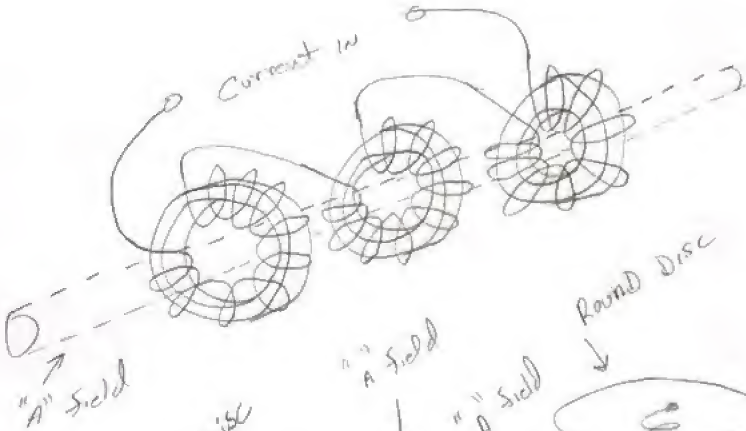
Best regards,

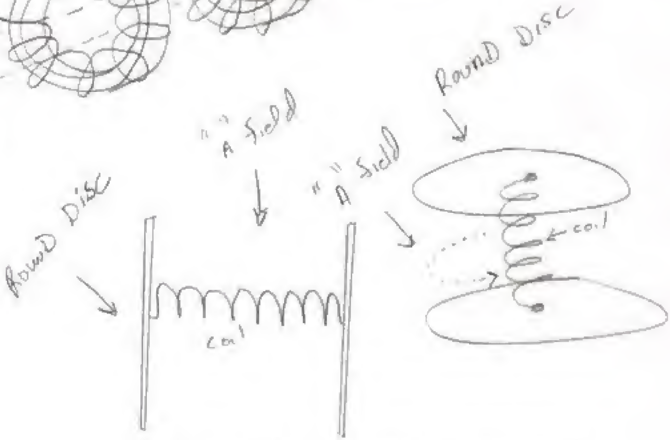
Harold S. Faretto

Hal J. Faretto

Encls.-drawing
HJF/gm







(this could be a tuned LC circuit.)

available. It increases the sucrose levels in sugar cane. Growers apply it sequentially, so that cane fields ripen in turn for harvest, rather than all at once.

/-on growth retardants are also in laboratory development. Homeowners anxious to avoid cutting the lawn might be eager customers for a product that "shuts off" grass growth at a desired height.

Super Magnets: The Race Is On

Japanese and American scientists are close to developing new, extra-powerful magnets for use in an astonishing array of products. The result could be a real bonanza.

A breakthrough in the development of more powerful and much cheaper magnets than those now available seems near, in both the U.S. and Japan. Since magnets are used to power everything from industrial robots and automobile engines to window air conditioners, such an advance has enormous commercial potential.

Powerful magnetic substances exist. American researchers developed a "samarium-cobalt" compound in the 60's that made possible the "Walkman" revolution in home entertainment. It has also found selective use in other products and as a scientific tool. But raw materials cost was simply becoming too high to allow widespread marketing.

The turning point came in 1978, when cobalt prices boomed, largely because of political unrest and instability in Zaire. The African nation is the major source of cobalt, and, because of its politics, an unreliable one. Moreover, cobalt is a strategic material used in military aircraft construction. Clearly, samarium-cobalt did not offer a viable answer to industry's need for more powerful magnets.

This year, the result of five years research is beginning to appear in the patent offices and on a limited basis on the marketplace. The new process combines iron—the old "reliable" of the magnetic business—with boron and "rare earth" metals. Tests have shown that the new magnetic compounds are more than twice as powerful as samarium-cobalt magnets and 15 times stronger than standard iron magnets. The major contenders in this race: General Motors, Sumitomo Special Metals of Osaka, Japan, and Colt Industries' Crucible Magnetics divison.

First out of the gate in announcing developments was Japan's Sumitomo. It has filed a large number of patents in the U.S. and elsewhere and is taking orders for their compound, which they call "Neomax." Delivery is set for fall. The firm claims it has produced magnets from Neomax substantially more powerful than the strongest samarium-cobalt magnet. The compound is a mixture of neodymium, a rare earth metal, and iron.

Crucible Magnetics has produced a high energy compound called "Crumax." Spokesmen claim it is even more powerful than Sumitomo's. "We have Crumax developed for various grade magnets, some well up into the high range," says Kalatur Narasimhan, the Crucible scientist who developed the product. The firm expects to begin commercial production this fall.

General Motors' entry is called "Magnequench." Details are sketchy because GM is keeping the technique under wraps. But, apparently, its scientists use a method in which molten metals are spun on a wheel and rapidly cooled. The resulting compound is not as strong or powerful as the others.

"Metal spinning strikes me as the hard way to go," says Carnegie-Mellon's W.E. Wallace. "If I were working for Ford I'd go the other route." He refers to a technique in which chunks of different metal are ground into a metal powder and then bonded.

But GM has one advantage. It owns its process. Proprietary rights over the grinding technique are much less clear. In fact, a patent war could develop out of Sumitomo's wholesale filing of them. Crucible's Narasimhan has already fired a warning shot: "We're confident about our patent position."

The next step for researchers, meanwhile, is making the new magnets more heat resistant. Many lose effectiveness above 100°C, not an unusual temperature for a starter motor in automobiles, one of the most lucrative areas for magnets, and their likely first commercial application.

Wallace says Japan is experimenting with adding some cobalt to the mix, and adds that Carnegie Mellon has itself developed a cobalt analog. He believes the heat problem will be solved within two years.

As for applications, they run across a wide industrial spectrum:

- **Variable DC Motors** for home appliances could open up a very significant market. Appliance cost would decrease sharply, while motors powering dishwashers or dryers would be twice as efficient as those in use today.
- **Computer peripherals** devour millions of magnets annually to spark the hammerbanks on printers. Japan has dominated this market so far.
- **"Mag-lev" or magnetic levitation trains** had excited scientists on three continents, but so far they have been unable to take bugs out of prototypes and ready them for commercial production. High energy magnets coming on the market could eventually make the difference.
- **Nuclear Magnetic Resonance** (see our issue of Feb. '84, page 3), which can image soft body tissues X-rays can't, could really take off once high energy magnets are used. They are cheaper, safer, more effective. So far, high cost has limited the system's general deployment.